

NOTES de RECHERCHES

**A SPATIAL INFORMATION SYSTEM FOR PREDICTING
HAZARD AT RAILWAY CROSSINGS**

Roger A. Roberge

\$3.50

October 1983

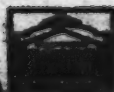
41

RESEARCH NOTES

**Department of
GEOGRAPHY**

**Département de
GÉOGRAPHIE**

UNIVERSITE d'OTTAWA



UNIVERSITY of OTTAWA

A SPATIAL INFORMATION SYSTEM FOR PREDICTING
HAZARD AT RAILWAY CROSSINGS

by

Dr. Roger A. Roberge

October 1983

Department of Geography
University of Ottawa

The transport of road and rail intersect at specific points in geographic space and the facility users sometimes come into contact often with disastrous results. In Canada there are about 34,000 railway-highway crossings on about 40,000 miles of railway tracks. The crossing accidents account for nearly 30% of all railway accidents and far more importantly comprise 60% of all fatalities arising from rail transportation. This represents about 150 fatalities and about 500 injuries each year at crossings [1]. In addition there are economic losses both to society and the railway companies. The problem of improving safety at railway crossings, therefore, is a major public concern. In a first section of this paper the concept of risk is examined and applied to railway crossings. A second section presents the Hazard Index model developed for the Canadian Transport Committee (CTC) and then applies it to the Windsor Quebec corridor. In a final section a spatial information system is described which has the potential of identifying hazardous crossings with greater accuracy.

I. Risk Analysis and Rail Safety Policy

Safety can be defined in different ways but in a transportation context, the following definition which emphasizes the probabilistic element has particular relevance for this paper [1, p. 1]

Safety is the state which results from the management of risk of damage inherent in the operation of a system involving men and machines

The key element in this definition is the explicit recognition of the concept of risk management. The concept that risk

cannot be entirely eliminated is one which has not as yet found common currency. For instance in industrial applications, it is possible to reduce risk associated with various operations but it is never possible to eliminate it entirely. What distinguishes railway highway crossing safety from other risk reducing operations is that it is theoretically possible to entirely eliminate risk by building grade separations. The elimination of risk at railway crossings however would involve an enormous expenditure of resources. In Canada for example, 31,000 crossings are not grade separated. If grade separations were to be provided at all crossings, it could cost as much as \$62 billion dollars. The fact that societies have not elected to eliminate all railway-highway crossings implicitly reflects the decision to accept some level of risk at crossings. The notion is thus introduced that one must evaluate the cost of reducing risk against the benefits derived in reducing damage through the lowering of the accident rate.

Some institution necessarily has to take on this responsibility of identifying and ultimately acting to reduce risk. The justification for having such a controlling agency is based on the distinction which is made in the literature between voluntary and involuntary risk. Voluntary risks arise whenever individuals or groups freely choose to assume certain risks which are not required as part of one's everyday routine activities. For instance one can

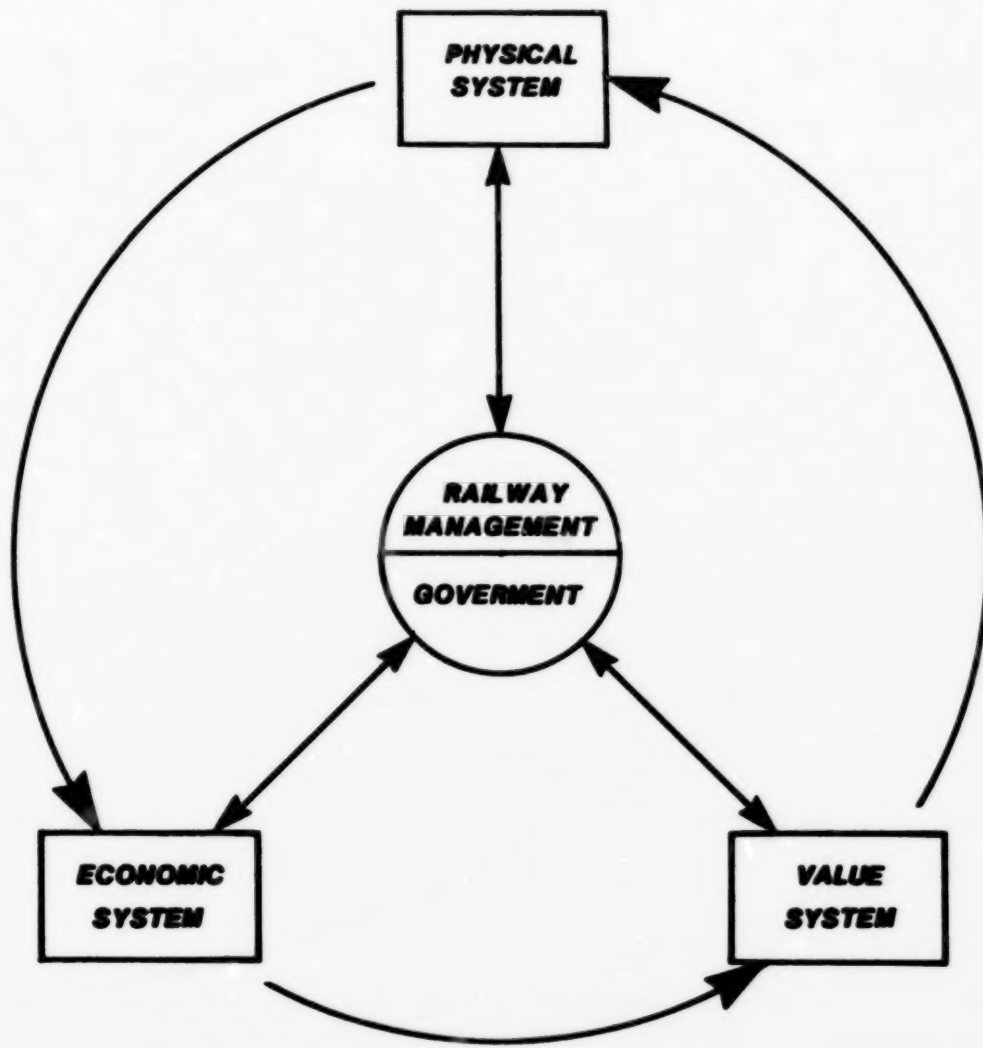
choose or not choose to engage in the recreational activity of sky diving. In this case one freely chooses to assume the risk. Involuntary risk arises whenever in the course of normal activities a certain amount of danger occurs. Transportation to and from one's employment is an example of this type of risk. In this case there is need for a controlling authority to intervene and manage those elements of risk that might arise.

The process by which risk is managed consists of three distinct but interrelated components: the physical system, the economic system, and the value system (Figure 1). In this model the function of the control group is seen as having three components [3]. They are as follows:

1. determine the level of risk acceptable to the society
2. develop a mechanism for identifying how the costs of reducing risk might be shared
3. identify the level of physical risk present in the system.

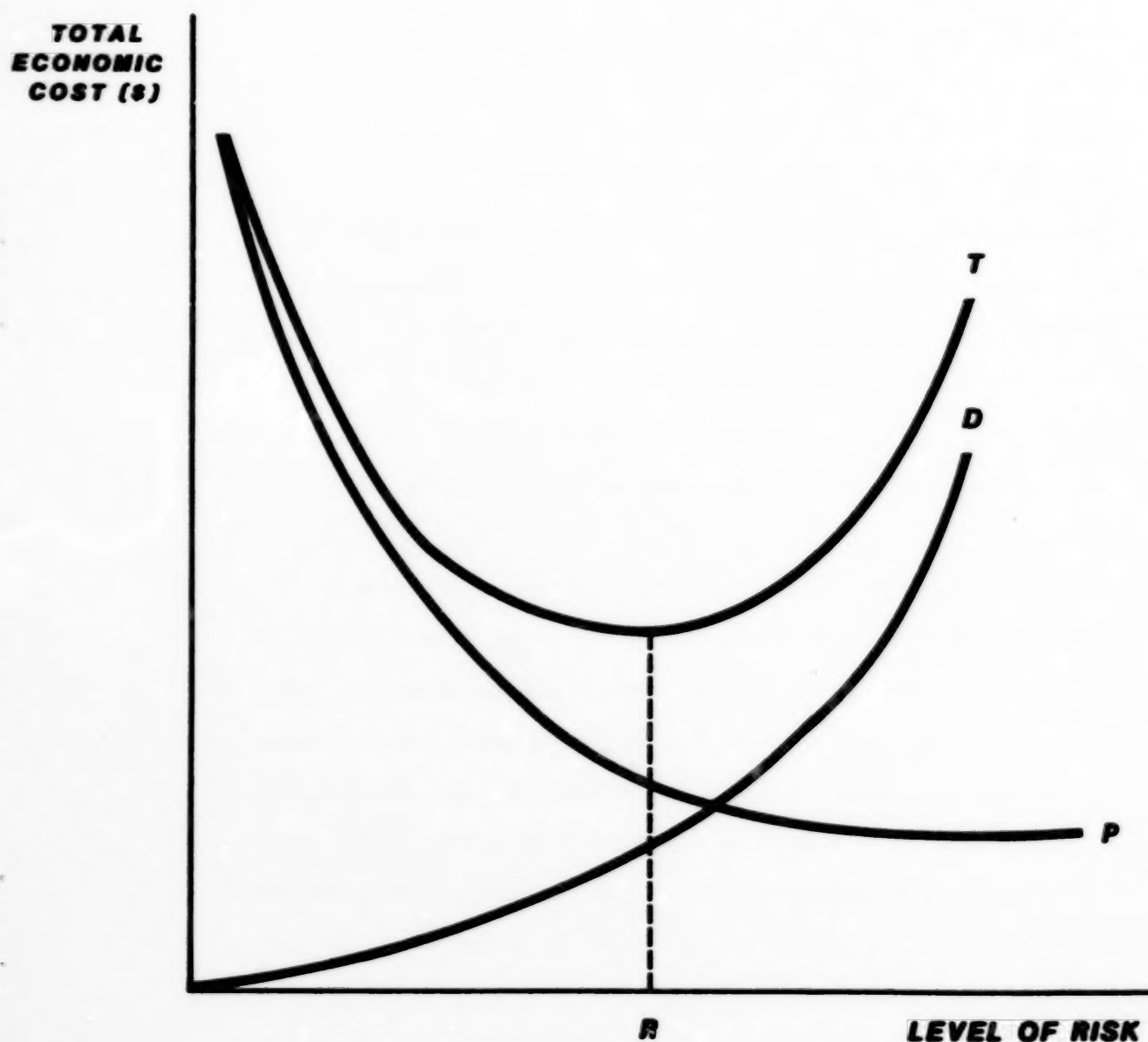
The determination of the level of risk acceptable to a society is complex and requires the balancing of expectations of the various groups in the value system encompassing the safety process. The expectations of the various groups are conditioned by the social, economic, and quality of life indicators which characterize a particular society. To a certain degree this level is defined by comparisons with other forms of transportation. Clearly government priorities also play an important role in arriving at this level in practice. Judging what level of risk a society is willing to accept is clearly not a simple exercise.

Figure 1: Risk reduction involves the management of three components - the physical, the economic, and the value system by institutions which in this case includes government and the railway companies.



One way in which to arrive at a measure of the level of risk reduction which a society is willing to achieve is to try to arrive at some monetary measure of the risk involved with various types of protection. It has already been indicated that risk at crossings could be eliminated by making them all grade separated. Clearly the sum needed to accomplish this task is not available. However lesser alternatives are available which reduce risk. Such an economic approach to risk management assumes that all costs can be monetized and that all accident prevention programs are cost efficient. Given these assumptions, it is possible to view the process of risk management as an unconstrained minimization problem where as indicated in Fig. 2, T is the total cost of maintaining various levels of risk, D is the total damage costs associated with accidents and P is the total accident prevention cost. The optimal level of protection is defined as that level where the cost of introducing protection devices is equalled by the reduction of damage associated with the installation of protection devices. This level is then defined as the economically optimal level. In theory such a solution is easily obtained. In practice however implementing such a program of risk reduction requires reliable estimates of physical risk associated with a given crossing. Furthermore because it is a national program it assumes a method capable of providing a system-wide evaluation of risk so that priorities can be established. The Hazard Index model developed for the CTC is an attempt to provide such a system wide evaluation of risk.

Figure 2: Risk management is viewed as an unconstrained minimization problem where T is the total cost of maintaining various levels of risk, D is the total damage costs associated with accidents, and P is the total accident prevention cost. The optimal level of protection is defined as that level where the cost of introducing protection devices is equalled by the reduction of damage associated with the installation of protection devices.



In the following sections the model will be first described and then applied to a region within Canada - the Windsor-Quebec corridor. A final section evaluates the model's performance and suggests possible improvements.

II. The CTC's Hazard Index Model

Traditionally the records of accident occurrences have been used as the only evidence of hazard at a crossing. Since this information is both ex post facto and only a partial indication of risk, another approach was developed for systematically evaluating risk throughout the system. In an attempt to develop a predictive model capable of measuring risk, the CTC developed a database with 31 attributes. These attributes can be grouped into the following six categories:

- a. Location and jurisdiction
- b. Accident history
- c. Protection at the crossing
- d. Truck and train characteristics
- e. Road and road vehicle characteristics
- f. Year of last inspection

By extensive use of common statistical procedures, such as stepwise regression and principle component analysis, it was clear that several variables had no relationship to the occurrence of highway railway accidents. These variables were eliminated from further analysis. Continuing in this vein a dozen four and five-way cross-tabulations were tested for a Poisson goodness of fit. This analysis showed that for any group which had the number of road vehicles as

one of its variables, the Poisson distribution was accepted at a level of significance equal to .10. This was not surprising since the use of a Poisson distribution for modelling accident occurrences has a long history in statistical annals.

In order to estimate the hazard at a crossing a large sample was drawn from the data previously described; the crossing accidents were regressed onto the explanatory variables available in the database for each crossing. By a stepwise procedure, the significant variables were identified and isolated. Because of the difference in the nature of urban as opposed to rural crossings, the model was partitioned into two equations, identifying the significant variables and explaining their contributions to the accident occurrence at each of the two type of crossings. Taken literally the model predicts the average number of accidents that will occur at railway-highway crossings in a five year period.

The format of the two equations developed for the national model is shown in Table 1. The urban and rural equations contain eight and twelve variables respectively. All of the variables shown in Table 1 are significant at the .95 level. The dominant variables in both the urban and rural equations are the train and motor vehicular traffic variables; although this is not necessarily obvious from the size of these co-efficients, the magnitude of the two traffic variables are such that the traffic at the crossing does explain the largest part, roughly 65%, of the hazard index associated

with a crossing. Zalinger in a validation of the model on a separate set of crossings at the national level reported that the hazard indices when compared with the accident histories of those crossings did provide a good estimate of risk at those crossings [5].

A group at the University of Ottawa was then asked to provide a regional validation of the model utilizing the Windsor to Quebec corridor as a particular case study. The corridor, as defined by Yeates, was selected because it was important to test the model's ability to predict risk in specific regional contexts [4]. The concentration of population in the axis (55% of Canada's population) coupled with the fact that 92 per cent of this population resided in census subdivisions containing an average population density greater than 50 persons per sq. mile contribute to a situation where accidents are likely to be more common. The expectation is confirmed by the data contained in Table 2. Clearly the axis' concentration of population and vehicular traffic is paralleled by a similar dominance in the accident statistics. Although the axis accounts for only slightly over a quarter of the crossings, it accounts for more than half the total number of accidents. A model whose objective it is to predict varying levels of risk associated with railway crossings must of necessity be accurate for this region.

In assessing the effectiveness of the hazard index model in explaining the rate of accidents within the axis, all locations for

Table 1
Variables in Hazard Index Model

TYPE OF VARIABLE	VARIABLE	COEFFICIENT IN URBAN MODEL	COEFFICIENT IN RURAL MODEL
DUMMY	Antiwhistling	.16984	
VARIABLES	Track Type	.13797	.03732
	Flashing Lights and Bells	-.07018	-.07325
	Gates	-.30607	-.14744
	Paved Roads		.11370
	Gravel Roads		.01938
QUANTITATIVE	In (No. of vehicles)	.05448	.04315
VARIABLES	In (No. of Trains)	.09045	.02302
	Width of Road	.00556	.00166
	Sightline		-.00583
	In (Speed limit of road vehicles)		-.04179
	In (Speed limit of trains)		-.03476
	Constant	-.39673	-.15310

Table 2
Percentage Distribution of Accident
and Non-Accident Crossings

	Total Crossings	%	Accidents Crossings	%	Total Accidents	%
Canada	33928	100	2847	100	4119	100
Windsor/ Quebec	9240	27	1381	48	2206	54

which an accident was recorded were retained in the analysis. In addition, in order to provide for a control group, a 10 per cent systematic sample was drawn. This sample which provided uniform spatial coverage was drawn from all the non accident locations. Altogether a total of 2304 crossing locations were included in the analysis. Table 3 provides a breakdown of the crossings by type of location. For each of the crossings, the hazard index was then calculated using the model developed by the CTC for the Canada wide validation i.e. the parameters of this equation were used in conjunction with the relevant variables taken from the CTC database to provide a hazard index for each crossing. The index was then used as an independent variable in a regression equation having the total number of accidents as the dependent variable. The coefficients of determination of these analyses are low though they are significant because of the very high number of degrees of freedom accorded by the disaggregated nature of the model.

In order to provide a clearer indication of where the model was weak, the crossings were next sorted according to their hazard indices and grouped into deciles. The accident total of the crossings in each decile was then determined. At the Canada wide level, the comparison of the hazard indices of crossings with their accident history showed that the model did provide a good estimate of hazard. An examination of a similar crosstabulation for the Windsor/Quebec axis indicates that although there is a trend toward more accidents as the index increases, there is no great consistency in the trend

Figure 3: The total number of accidents over a five year period is distributed over the hazard levels categories defined in the CTC model.

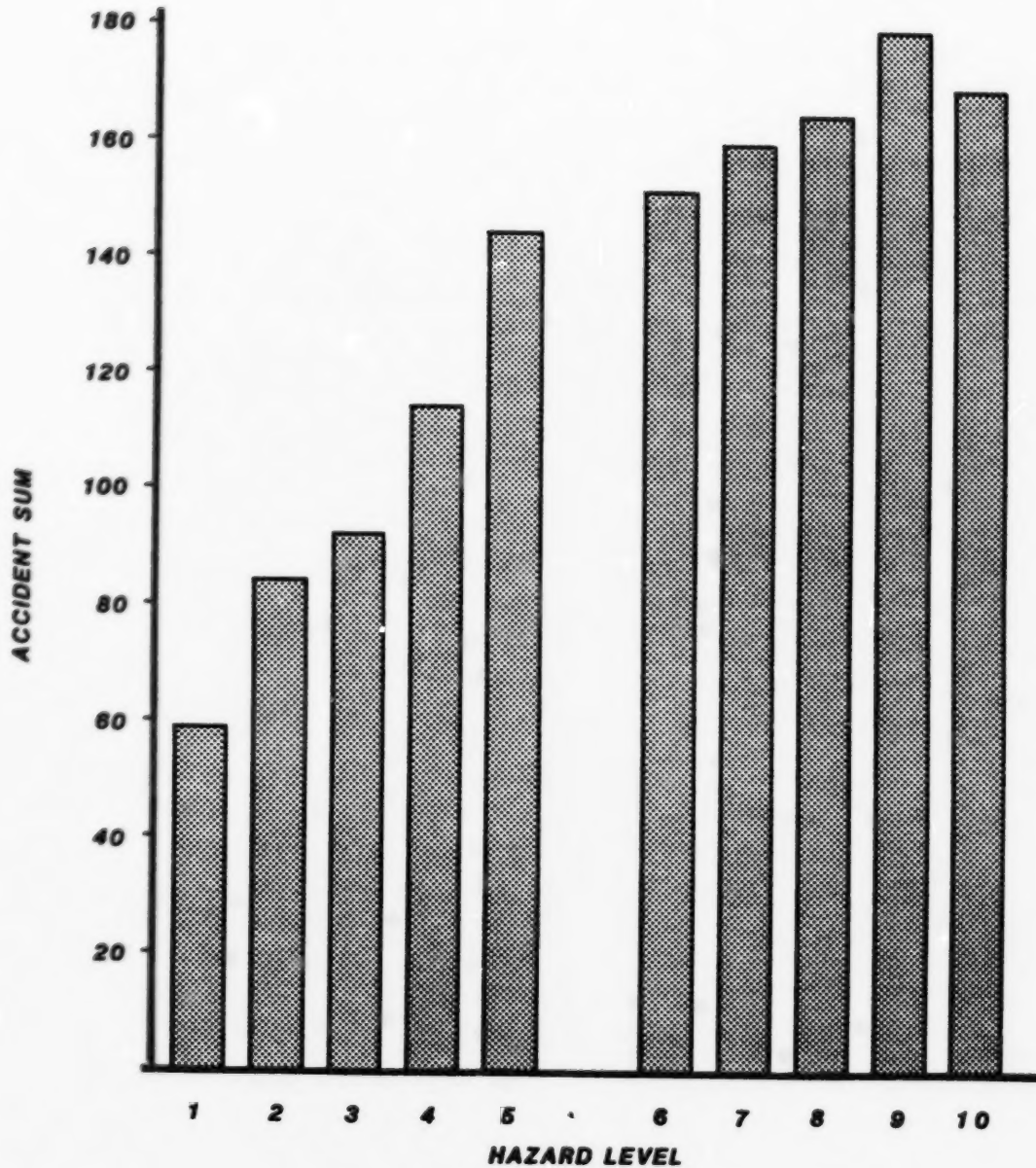


Table 3

Railway Crossings (By Type)

	All Crossings	%	Accident Crossings	%	Sample Crossings	%
Urban	1359	59	860	62	499	54
Rural	945	41	521	38	424	46
Total	2304		1381		923	

Table 4

Distribution of Hazard Indices
(Percentiles, From Least to Most Hazardous)

No. of Accidents	1	2	3	4	5	6	7	8	9	10
0	86	63	63	50	41	39	38	33	30	56
1	41	63	56	64	55	64	55	62	56	27
2	9	9	15	13	25	18	22	21	24	23
3	0	1	2	8	13	17	20	20	25	32
Totals	136	136	136	135	134	138	135	136	135	138

(table 4). It appears that above a certain threshold, the incidence of accidents is quite similar. This impression is confirmed by an examination of Figure 3 which shows the total number of accidents for the ten hazard levels. Starting with hazard level five, the increase in the total number of accidents increases in the initial hazard levels at a significant rate. However starting with the fifth decile, the increase in the number of accidents increases only marginally for the remaining levels and actually decreases in the tenth and final decile. The only clear trend appears to be a greater frequency of multiple accidents at crossings as the index increases in value.

One reason for the weak level of prediction which the Hazard Index model achieves in the Windsor to Quebec corridor is probably due to the fact that the key variable, vehicle counts, is subject to systematic underestimation in regions where population growth is rapid. Since the rate of population growth in the axis was two and half times that for Canada as a whole for the period under investigation, accurate vehicle counts for each crossing cannot be assumed for all crossings on the CTC database. Partial evidence for this conclusion is provided by the Ministry of Transportation and Communications of the Province of Ontario [2]. This publication provides a summary of traffic volumes and accident rates on all provincial highways and secondary roads. A sample set of locations is provided in Table 5. The direction of the bias is generally on the low side. The low estimates generally are in agreement with

Table 5

Comparison of Traffic Volume Estimates

Subdivision Number	Subdivision Name	Record Number	C.T.C. Estimate	Highway Number	Summer Average Daily Traffic	Winter Average Daily Traffic	Direction of Error
658	Smith's Falls	145484	5000	15	4475	2425	H
016	Belleville	189672	500	41	2200	1200	L
016		189466	1400	38	2900	1775	L
361	Campbellford	21139	5000	50	5400	3325	OK
016	Belleville	190249	1600	02	4900	3550	L
433	Forest	58984	3200	04	6000	4700	L
453	Guelph	172742	18000	85	13000	10500	H
377		31659	8500	03	8300	6500	OK
903	Penn. Central	326240	15000	03	11750	4450	H
900	" "	323098	2000	18	6150	5000	L
453	Guelph 2	14284	2000	06	20500	16500	L
089	Havelock	228636	2000	28	14525	9575	L
	Forest	58950	2000	23	2050	1275	OK
089	Havelock	228925	7000	07	7850	4800	OK
135	Mactier	250134	5000	90	8825	6775	Low
176	Orangeville	264052	500	07	9750	7550	

Source: Ministry of Transportation and Communications, 1976 Traffic Volumes.

informed opinion which indicates that generally the CTC estimates are seriously underestimated.

The high estimates are probably due to recording errors. That there are errors in such a large database is not surprising. Finding errors related to vehicle counts is difficult however. For instance one knows that there are no automobiles or trains which operate at 600 m.p.h. Such observations can in fact be eliminated from analyses. However it is less clear when the vehicle count, the most important variable in the model is in error. The error in coding a crossing as having 5000 vehicles when in fact it has 500 is not immediately apparent. To provide for potentially more accurate forecasts of hazards, there is need integrating other sources of information into the CTC database.

III. A Spatial Information System

Given the need to allocate resources among crossings, it is necessary to identify accurately the most hazardous crossings. An alternative which provides for a more general indication of not only where erroneous data may be present but also allows for forecasts to be made involves the incorporation of socio-demographic data into the CTC database. This ultimately involves matching census data with the CTC data at the level of the individual crossing. At present there exists only one variable that can be used to concatenate CTC data with Statistics Canada data - that is the electoral

district. However this unit is much too large to provide an accurate basis for checking the vehicle counts on the CTC database since there may be as many as 100 crossings in an electoral district.

Since the CTC file had its spatial designators not only coded in alphanumeric form but also ranging from specific place names to very broad designations such as counties, the task of geo-coding turned out to be long and tedious. The result however was the inclusion on the data file of a U.T.M. code which uniquely identified each crossing in space. These codes made it possible to append to the CTC file the economic and social information necessary for assessing the broader environment of each railway crossing. Thus it was possible to map any characteristic on the CTC data base as well as the associated socio-demographic variables. The final step in the process was the development of a computer graphics program which could present any segment of the region at whatever scale deemed necessary.

As a preliminary test of the system's utility in identifying problem observations, two variables namely road width and a socio-demographic variable which defined settlement type were used to predict vehicle counts. A multiple regression framework was used and the resulting analysis of residuals provided a means for identifying those observations which were either seriously under or overpredicted. The results of the sample test indicates that the average crossing had a mean value of 3,135 vehicles per day with a

standard error of estimate of 4,035. Thus a standardized residual of greater than 2.0 would be out by as many as 8,000 vehicles per day. The plot of residuals above the mean indicated that the positive residuals were randomly distributed while the negative residuals were linearly associated. This seemed to indicate a random pattern of errors associated with large positive deviations, an interpretation which is consistent with coding errors. The systematic underprediction, on the other hand, indicated those crossings which have not had recent updates in their counts.

The inclusion of socio-demographic data however not only provides a basis for making consistency checks but it also makes possible forecasts of future vehicle flows. This is possible because the definition of the fuller environment of the railway crossing can include those aspects of settlement type that have a direct bearing on traffic patterns and flows. For example income levels may reflect car ownership intensity, and settlement function (e.g. dormitory suburb, rural distribution center, industrial center) can affect corresponding traffic patterns. Once a typology of settlements types has been established, it is possible to relate population to area transportation requirements for total internal person trips, demand for mass transit or private automobiles, as well as trip purpose i.e. return home, work, shopping, social-recreational and miscellaneous. An intensity index can then be constructed and rail crossings identified which either have low levels of protection for their level of development or might become dangerous

because of rapid social and demographic change.

Conclusion

Although a rough idea of hazard can be obtained intuitively, it is difficult if not impossible to assign a systematic hazard ranking to all 34,000 crossings in Canada. In this paper we have reviewed the concept of risk and shown that for railway crossings, the concept is one which is capable of being quantitatively measured and as a result an index of risk for the 34,000 crossings in Canada can be constructed. Hence the most obvious application is the provision of systematic, comprehensive, and objective set of hazard indices for the crossings. An application of the model developed for Canada as a whole to the Windsor-Quebec axis was less successful. The model's weakness at the regional scale was seen to be largely due to problems with the key variable in the estimating equation-vehicle counts. Suggestions for further refinement of the model were made which would require the incorporation into the CTC database of variables capable of providing a means of identifying erroneous values as well as providing a possibility of predicting likely changes in the relative level of hazards associated with differential population growth or functional changes. Clearly however other variables directly related to the crossing environment would also have to be included. Such important information as the time of day of an accident can be useful in providing some insight into the cause of accidents. For instance at those crossings where a "peaking" phenomenon exists, the impatience of drivers might lead to accidents which would be discernible if the time of day of accidents

were noted. Similarly data on the date of the accident and the weather conditions in existence at the time might have a bearing on the explanation of accidents. Other variables could be suggested but it would have to be determined how much more effective the model would become in predicting accidents since the costs of collecting and updating this information for the 34,000 crossings in Canada would be enormous.

Given the possibility of predicting risk at individual crossings, the model can then be used as a basis for developing a cost-effective risk reduction program. The model can be used in this regard to shed light on the components of crossing hazards and thus calculate the effects of risk reduction by the alteration of the various characteristics of the model. For example the model could be used to indicate the risk reduction that can be achieved by upgrading the automatic protection devices at crossings. Furthermore when hazardous crossings are cartographically identified, inferences concerning the similarities can further assist in identifying other factors.

Literature Cited

1. Johri, Hari; Milne, Joseph; Wright, Richard; "Government Regulation and Rail Safety", Paper presented at NATO Conference on Environmental Assessment of Socio-Economic Systems, Istanbul, Turkey, October, 1976.
2. Ontario Ministry of Transportation and Communications, Systems Analysis Office, 1976, Traffic Volume on King's Highway and Secondary Highways, Toronto, 1977.
3. Starr, Charles, "An Overview of Public Safety Problems", American Society of Safety Engineers, July, 1969, p. 65-105.
4. Yeates, Maurice, Mainstreet: Windsor to Quebec City, Toronto: Macmillan Co. of Canada, 1975.
5. Zalinger, David; Rogers, Betty; Johri, Hari, "Calculation of Hazard Indices for Highway-Railway Crossings in Canada", Technical Paper, CTC, mimeo, 1977.

NOTES DE RECHERCHE / RESEARCH NOTES

- * 1. P.G. Johnson, "The Degradation of the Donjek Glacier Neoglacial Moraine, St-Elias Mts., Yukon Territory, Canada", 9 p. February 1972, \$0.50.
- 2. C.L. Dudley, "A Note on Reinvestment Assumptions in Choosing Between Net Present Value and Internal Rate of Return", 9 p., September 1972, \$0.50.
- 3. L. Ploegaerts, "Etude critique et comparative des plans d'urbanisme et de développement municipaux préparés depuis 1967 sur le territoire de la Communauté Régionale de l'Outaouais", 81 p., Mars 1973, \$1.25.
- * 4. J.E. (McCabe) Albert and P. Harrison, "Jurisdictional Problems of New-Brunswick Coastal Zones", 32p., May 1974, \$1.50.
- 5. C.L. Dudley, "A Theoretical Financial Analysis of the Long Term Subsidy Value of the Regional Development Incentive Program in Canada: 1969-1972; A Summary", 32 p., October 1974, \$1.50.
- 6a. M. Kugler-Gagnon, "Computer Processing of Geological and Geotechnical Data for Urban and Land-Use Planning", 29 p., March 1975, \$1.50.
- 6b. M. Kugler-Gagnon, "Traitement informatique des données géologiques et géotechniques pour l'aménagement urbain et péri-urbain, 28 p. Mars 1975, \$1.50.
- 7. C.L. Dudley, "The Weakness of Financial Location Incentives in Promoting Regional Development", 39 p., April 1975, \$1.50.
- 8. P. Harrison, "Spatial Externalities and the Problem of Resource Control", 15 p., May 1975, \$1.00.
- 9. P.G. Johnson, D. Cossette, D. Conway, C. Lok, "Preliminary Report: Environmental Controls on Geomorphologic Processes, Grizzly Creek, South West Yukon Territory", 108 p., August 1976, \$4.00.
- * 10. L. Ploegaerts, "Etude comparative des plans de zonage sur le territoire de la Communauté Régionale de l'Outaouais", 95 p., Mai 1976, \$4.00.

* Réserve épuisée / Out of stock



11. G.P.F. Steed, "An Historical Geography of the Canadian Clothing Industries: 1800-1930's", 52 p. November 1976, \$2.75.
12. R.A. Roberge, "Investment Decisions, Comparative Costs, and the Evolving Location Pattern of the Canadian Pulp and Paper Industry", 38 p., December 1976, \$2.00.
13. P.F. Ricci, "Spatial Analysis Through Carrying Capacity", 24 p., Janvier 1977, \$1.75.
14. P. Harrison, "Spatial Demand Under Conditions of Substitution: A Disgrammatic Exposition", 20 p., February 1977, \$1.50.
15. P.F. Ricci, "From Public Announcement to Completed Construction: A Study of the 12 year Impact of a Water Resource Project on Property Values", 23 p., June 1977, \$1.75.
16. P.F. Ricci, and V. Maclaren (ed.), "Selected and Annotated Readings on Planning Theory and Practice", 72 p., September 1977, \$3.00.
17. R. Wesche, "Modern Agricultural Settlement in Rondonia, Brazil", 31 p., August 1977, \$1.50.
18. P. Harrison, "Decision Information and Coastal Management: Some Preliminary Remarks", 15 p., August 1978, \$1.50.
19. A.G. Lewkowicz, "An Approach to the study of Surface Wash: The Case of the Laboratory for Experimental Geomorphology, Leuven, Belgium", 42 p., April 1978, \$2.50.
20. V. Berdoulay, "Notes sur les idéologies comme l'objet d'étude géographique", 23 p., Mars 1979, \$1.75.
21. S. Ansari, "Spatial Variations in Levels of Socio-Economic Development of Ontario and the Industrial Structure: an Empirical Test", 66 p., March 1979, \$4.50.
22. D.A. St-Onge, "Forages au roc, Région Nord de Montréal", 113 p., Juillet 1979, \$8.00.
23. M. Phipps, "Information Theory and Spatial-Ecological Analysis: The "Pegase" Procedure, 45 p., 2 fig., September 1979, \$3.00.
24. G.P.F. Steed and M. Appana, "Preservation, Rationalization and Orderly Adaptation: Canada's Footwear Sector", 35 p., September 1979, \$2.50.



25. Felix A. Kwamena and Peter Harrison, "Canada's Offshore Resources: Frameworks for Management", 215 p., November 1979, \$12.50.
26. Peter Harrison, "Managing Canada's Ocean Area: Institutions, Client Groups, and Co-ordination", 30 p., December 1979, \$2.00.
27. Felix Kwamena, "Canada's Offshore Resources: The Problem of Integrated Planning in Canada's 200-mile Economic Zone", 27 p., December 1979, \$2.00.
28. Peter Harrison, "Canada: Energy Futures, Energie et l'Avenir", 61 p., April 1980, \$5.00.
29. Michel Phipps, "Recherches écologiques pour l'aménagement forestier: Les Cédraies du Moyen Atlas du Sud-Ouest."
 - a) Le contexte, 38 p., juin 1980, \$2.50.
 - b) L'approche méthodologique et l'espace écologique, 75 p., janvier 1981, \$5.50.
 - c) Les types de communautés végétales, 122 p., mars 1981, \$5.50.
30. Guy Steed, "National Circumstances, Expectations Conflict and Compromise: Canada's Textile and Clothing Policy", March 1981, \$2.50.
31. Peter Harrison, Charles Brassard, Donald Wright, "Capital Expenditures to Develop the Hibernia Field: Sectoral and Spatial Distributions of Impacts", June 1981, \$3.00.
32. Edmond Kayser, "Les routes et le développement des transports au XIXe siècle: la formation des réseaux luxembourgeois", 32 p., Août 1981, \$2.50.
33. Don Tate, "The Analysis of Manufacturing Employment in Canada Using Shift-Share Analysis: An Examination of Methodology and an Empirical Test", 66 p., December 1981, \$6.00.
34. Véronique Dewez et Daniel Lagarec, "La dualité glaciaire - périglaciaire et l'origine de certaines formes dues à la fonte de glace", 77p., juin 1982, \$7.00.
35. Ghyslain Poulin et Michel Phipps, "Ambiance et structure forestières: Une méthode d'approche pour l'étude du loisir en forêt". 33p., août 1982, \$2.50.
36. Marie-Anne Geurts, "Observations géomorphologiques dans la région de Huamachuco, Andes centrales péruviennes", 27 p., octobre 1982, \$2.50.

UNIVERSITÉ D'OTTAWA



UNIVERSITY OF OTTAWA

37. Roger D. Needham, "The Cosmopolite - Localite Model: Newspaper Types and Natural Hazard Information Potentials", 42 p., November 1982, \$3.50.
38. Pedro de Almeida Vasconcelos, "Le secteur informel urbain", 81 p., Septembre 1982, \$7.00.
39. Marie-Anne Geurts, D. Lagarec, F. Sarrazin et S. Lemaître, "Pluie Pollinique de l'été 1982 dans la vallée du Gladstone Creek (Yukon), Mai 1983, \$4.00.
40. Michel Phipps, "Etude d'un processus de recolonisation par le cèdre (Cedrus Atlantica Man.) Analyses de configuration du peuplement", Mai 1983, \$6.00.
41. Roger Roberge, "A Spatial Information System for Predicting Hazard at Railway Crossings", 24 p., October 1983, \$3.50.
42. Anne Gilbert, "Les abandons de ferme et la concentration de l'habitat dans l'Outaouais rural québécois", Ingo Eberle (Mayence), traduit par Anne Gilbert (Ottawa), sous presse.